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## Economy Controls Energy Retrofits of Danish Single-family Houses

*comfort, indoor environment and architecture increase the budget*

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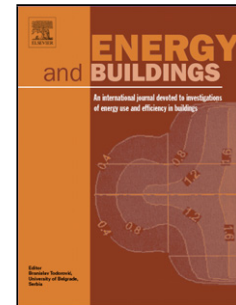
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# Economy controls energy retrofits of Danish single-family houses

## Comfort, indoor environment and architecture increase the budget

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**ABSTRACT:** A great energy saving potential is found in the 440,000 Danish single-family houses erected between 1960 and 1979, but the potential is not exploited. To utilize this potential homeowners must be motivated to conduct energy saving retrofits. This paper presents results from a survey from 2012 where 883 Danish single-family house owners completed a questionnaire about energy retrofit. The objective of this paper is, based on the survey results, to determine how Danish homeowners can be motivated to conduct energy retrofits.

The conclusion is that the financial aspect of an energy retrofit will always carry great weight for the homeowners and is often the reason why energy retrofits are not carried out. Improvements in comfort, indoor environment and architecture have nevertheless proven to be motivating for the homeowners and to increase the budget for retrofits. However, not much knowledge about the potential improvements within these parameters is found among the homeowners and therefore there is a vital need for more information about this. A combination of this knowledge of the non-economic improvements, a sensible investment size and information and education about the current situation and consumption is concluded as the optimal motivation strategy for the homeowners to conduct energy retrofits.

*Keywords: Energy retrofit, motivation factors, homeowners, indoor environment, comfort, architecture, economy.*

## 1. INTRODUCTION

The European Union has set up objectives for future energy savings across all sectors and countries and aims for a 20% decrease in the primary annual energy consumption by 2020. The building sector is responsible for around 40% of the total energy consumption. Therefore, there is a great need, not only to keep new erected buildings to a minimum in terms of energy consumption, but also for energy retrofit of the existing building stock if the objectives of the European Union should be realistic [1]. The current retrofit rate is much too low to attain the objectives, and some effective motivation is needed especially for the private homeowners who have to invest in the projects with private funding [2]. In Denmark, single-family houses are one for the most dominating housing types for private persons with close to 80% of all housing buildings [3], and therefore this type is the underlying basis for the study about motivation factors for private house owners. Around 40% of the Danish single-family houses were erected between 1960 and 1979 (440,000 houses) [3]. In these and the coming years, these houses are ready for deep retrofit to different extents due to their age. Some have had work done, but the majority has not been renovated yet [4]. When these houses are retrofitted, it is crucial that energy saving initiatives are included in the processes both to future-proof the buildings, to cut down on the energy demand, but also to ensure better living conditions for the homeowners. The single-family houses built during the period mentioned total a probable saving potential of up to 7,811 TJ [5], and for this potential to be utilised the homeowners need to be motivated to incorporate energy saving initiatives in their future retrofit projects. The Danish building sector has in previous years been very focussed on and successful in the development of new erected low energy buildings and the skills needed in this area. The sector is now facing the challenge of bringing the same skills into play in the existing buildings by retrofits. However the homeowners need to be motivated to perform energy retrofits in order for the acquired skills to be utilised in an optimum manner and with the largest possible energy savings as a consequence.

This paper focuses on results from a survey carried out in January 2012 where 883 homeowners out of 4,000 invited completed a questionnaire about energy retrofits. The first part of the paper briefly describes the choice and design of the method and approach. The second part presents results from the questionnaire survey with attention towards the homeowners' view on energy retrofit, on important parameters in the home, and on the need and will to retrofit. A discussion about the results follows hereafter, and finally the paper finishes with a conclusion on how the homeowners can be motivated in the future.

The study is carried out in Denmark in the Northern Europe, but the questionnaire can nevertheless with some alterations according to country and building type be implemented in various countries facing the same issues as Denmark and among various building typologies. The majority of the questions is general questions and can be used as they are without attention to the present country and with equal relevance. The presented examples of

architectural changes ought on the other hand to be adapted to the building traditions of the specific country. The questionnaire is developed with homeowners as respondents and would require some additional adjustments to be suited for a respondent groups consisting of renters.

## 2. STATE OF THE ART

A previous literature review [6] concerning the barriers for energy retrofit deals with three different trade groups: homeowners, architects and contractors, and the different barriers and possible solutions to overcome these. This was done since it cannot be stated that the owners are the only ones to stop the process of retrofits; many other trade groups also experience barriers [7]. The studied literature have investigated and described the saving potential and barriers and following presented possible solutions to overcome these mainly by gathering other reports and calculations, performing interviews or debates with key persons or groups and conducting a small questionnaire survey [7-12]. The literature survey concluded that the homeowner is the user group to focus on in order to change the current situation and increase the number of deep energy retrofits [6]. The barriers for the homeowners reach from economy and uncertainty about aesthetics and savings to lack of knowledge and interest, and therefore the solutions are not easily determined [7,9-12]. The authors trust nevertheless that if incentives are generated for the homeowners and they insist on deep energy retrofits, other trade groups such as architects, engineers, financial sector, politicians, manufacturers etc. will follow. It is seen as a question of supply and demand.

The survey and results presented in the present paper investigate via a questionnaire survey whether some of the proposed solutions are actual solutions to overcome the barriers faced by homeowners or if other initiatives could be more beneficial in the future. One of the main problems described in various surveys is related to the lack of interest and knowledge [7,9-12], and therefore the next step should focus on determining the knowledge level and finding potential motivation factors for the average Danish homeowner [6].

A German study from 2012 [13] has examined the impact of one way of providing the homeowners information; the energy performance certificates (EPC) introduced by the European Union. EPCs were introduced by the European Union to overcome one of the barriers for energy efficient upgrading of the existing building stock: "imperfect information". The EPC should help future homeowners and renters to incorporate energy efficiency in their decision making process and thereby saving CO<sub>2</sub> due to more informed decisions. The study shows that the EPCs so far have had only little effect nonetheless it has a clear potential, but some barriers need to be removed before the full potential can be utilised. In the case of the EPC there were some issues of among others lacking trust in the information given, an economic side of the certificate which were not optimal and the location and other house related aspects weighing more in the decision for the homeowners than energy efficiency [13]. This is an example of that although valid information is present it is not necessarily enough for the

homeowners to be motivated for energy efficiency. It takes more than just information and this survey examines what else is needed for the Danish homeowner to be motivated.

Tuominen, Klobut, Tolman, Adjei and Best-Waldhober have studied the barriers for energy retrofit in Europe and the potential if the barriers are removed [2]. The study included ten European member states. Some of the barriers found consistently for privately owned dwellings in the ten member states are; lack of effect on property price, the consumers don't request energy efficiency, lack of (trustworthy) information, poor training and skills of the professionals and lack of appropriate, affordable financing. Different policy instruments have been utilised to overcome the barriers and among the most widespread are subsidies for energy efficient retrofits, information and tools, regulatory demands and ecological taxation. However the profit of all the instruments have yet to show its true potential on the amount and depth of energy retrofits if the energy savings potential of 2020 and 2030 should be realistic.

*"It seems that in most countries cost-effective energy savings of about 10% can be achieved by 2020 and 20% by 2030. A total annual energy saving of approx. 150TWh by 2020 and approx. 280TWh by 2030 appears possible."*[2]

That is the barriers faced are to a certain extent the same all over Europe and the potential energy savings by retrofits are huge if the barriers can be removed. Therefore the definition of the motivation factors for homeowners to perform deep energy retrofits are important and crucial, not only in Denmark, but all over Europe combined. This to utilise the potential defined and to fulfill the objectives established either by the European Union or by the respective governments in each country.

If the homeowners can be motivated to think about and include energy savings when they conduct retrofits, a big reduction in the Danish energy consumption could be made and also in other countries who are experiencing the same barriers. Previously, the Danish motivation strategy has mainly focused on economy and payback time, but the timespan has been too long for the homeowners [7,9], and therefore no action has been taken. Other parameters, which cannot be converted into money, are expected to motivate the homeowners [6,8-11]. This paper investigates whether or not homeowners will, in fact, conduct energy retrofits if they get visible and perceptible non-energy improvements or if they find energy savings in itself sufficiently motivating.

### **3. METHOD USED**

#### **3.1. In general**

There are different methods to use in social research, and the main two are the quantitative and the qualitative method which both contain various approaches. There is also a third method which is a combination of the two known as mixed methods [14]. Whether one or the other method is used depends on the project's framework conditions, resources and which data are needed to fulfill the objective.

A previous study concerning the barriers for private energy retrofits of single-family houses can be followed by various different scientific methods. The main problems found were related to the lack of interest and motivation, and therefore the next step should focus on the identification of these for the average Danish homeowner [6]. The objective of the survey presented in this paper is to define the Danish homeowners' knowledge level, preferences and motivation factors for energy retrofits of approximately 440,000 privately owned single-family houses from the 1960s and 70s. This means that the most useful result of the survey is a generalization and a wide picture of a group of homeowners, their preferences and which factors can be used to motivate them to conduct energy retrofits. Therefore, it is crucial to get a sufficiently high amount of respondents, which is why the quantitative method has been chosen.

In quantitative research, the data is generalizable, and the respondents can be a group of selected representative persons instead of key persons. Some of the main differences between quantitative and qualitative methods are that when using qualitative methods the data is often in-depth information provided by a small number of key persons, who give their own view of a subject in e.g. an interview. Where quantitative methods instead provide data which gives an overview of an investigation field or an average response from a large group of selected persons [14]. In this case, where the results should be used to motivate as many as possible of 440,000 households, the average is more important than the details, and the larger a group of respondents asked the more precise the average will be. Furthermore, the quantitative method gives the possibility for a large geographic spread since there is no need for personal contact with each of the respondents. This means that the respondents group can be spread across the same area as the results should later be used on, in this case Denmark, and so give a more precise picture of the total.

Moreover, the amount of respondents in the survey can be larger, within the same timeframe, because all respondents get uniform questions, and the process is very structured hence the data is relatively easy to process compared to data from a qualitative method. It is often said that qualitative methods generate soft data (personal answers and feelings) whereas quantitative methods generate hard data (average of the group). This since a qualitative approach often includes an open interaction or dialog with the person(s) providing information while a quantitative approach will be programmed and will limit the gathered information to predesigned questions or schemes.

The most common way to conduct quantitative surveys is to use a questionnaire which will also be the approach of this study. The questionnaire can be constructed in various forms, and the following chapter will briefly describe the design of the questionnaire.

### 3.2. Design of the actual questionnaire

There is no conclusive solution to breaking down the known barriers and to motivate the homeowners to energy retrofits. The previous research studied [6] has focused the knowledge gathering around various groups of professionals, and the highest amount of homeowners included in a survey is 48 households [9]. This survey only includes homeowners. Since they are the ones to motivate, it is found crucial to ask them about their opinions on the subject and how to change the present situation.

The geographic spread is determined by the geographic location of the target group and should preferably cover the same area as the target group in order to get a usable result, covering the whole target group. 4,000 questionnaires were sent out to 1,000 homeowners in the suburbs of respectively Aalborg, Aarhus, Odense and Copenhagen, and thereby the respondents were spread across the country in order to make a final statement about the average Danish single-family house owner [figure1].

[figure1]

The questionnaire used for the survey is divided into five themes, mainly to make it more visual and easy to go through for the homeowner since the amount of questions may be overwhelming. The five themes are: 1) General information about the respondents, 2) Energy consumption and retrofitting, 3) Architecture, 4) Comfort and indoor environment, and finally 5) Economy.

For the survey to be conducted in other countries or with other building types as study area the part about architecture needs to be redesigned to match the building tradition of the country and/or the building typology studied. The financial opportunities listed in the economy part likewise have to be adjusted to the opportunities in the given country. The remaining questionnaire can be applied as is.

All respondents were selected by random selection conducted by the use of information from four district heating companies in respectively Aalborg, Aarhus, Odense and Copenhagen. The district heating companies were asked to name homogenous neighborhoods of a certain size within their customer areas where single-family houses erected between 1960 and 1979 and connected to the district heating system are found. 1,000 single-family houses in each of the four areas were randomly selected to receive the questionnaire, and their names were found by the use of the webpage [www.ois.dk](http://www.ois.dk), where each house was also checked for the right time of construction. It was chosen to focus on the houses connected to the district heating grid since this is the most common energy distribution form in Danish buildings and 45% of all households are connected to this system [3]. Primary alternatives to the district heating are central heating with either natural gas or oil, which is used by respectively 21% and 20% [3]. Heating by electricity, stoves and heat pumps are mainly used in buildings only where it is not possible to connect to the district heating grid due to a location far from the distributor.



The respondents are promised anonymity in the accompanying letter in relation to their answers and personal information. The researchers are, however, in possession of personal information such as name, address, phone number and email of the majority of the respondents, but this information will not be published. 85% of the respondents chose to give the information in relation to a competition in the questionnaire in order for the researchers to contact the winning homeowners.

#### **4. SURVEY REPRESENTATIVENESS**

##### **4.1. Respondents and statistical data**

A large majority of the respondents who completed the questionnaire are men; the respondent group consists of 65% men and 35% women. This picture of a population of 65% men in the single-family houses is not similar to the actual statistical data. The amount of women and men is, according to Statistics Denmark, very close to equal in these houses across Denmark with 49.2% women and 50.8% men above the age of 18 [figure 2][15]. The different gender distribution of the respondents can be caused by the fact that the letters were addressed to a person in the house listed as the owner. If two persons were listed, the first mentioned was used without attention towards the gender. In the houses where the first owner is still living or where older people live, the owner will traditionally be the man. This means that the receiver of the letter in many cases was a man, and therefore there will naturally be an overweight of men replying – if the receiver of the letter is in fact also the person replying.

[figure 2]

The average age of the respondents (57.5 years of age) is higher than the average of the statistic homeowner. When the different age groups are compared [figure 3], it is easy to see that the respondent group consists of more people above 50 years than the statistics [15]. The difference is very significant for the group between 60 and 70 years of age. The reason for this division could be that either the letters did not go out to enough of the younger generation to be representative or that this generation did receive a letter but did not reply.

[figure 3]

The respondents were asked for how long they have lived in their current house, and 59% have lived there for more than 20 years. Furthermore, the average age of the respondents consists with the fact that 42% of the respondents are retirees or receivers of early retirement.

The geographic spread of the respondents is evenly divided since the questionnaire was sent to an equal amount of people in each region. The statistical spread of the single-family houses in each of the regions is different from the spread of the respondents. Copenhagen and surroundings have 31.53% of all single-family

houses in the four regions followed by Aarhus with 25.34%, Aalborg with 23.93% and Odense with 19.20% [16]. The numbers from Statistics Denmark are for the four different cities (only for Copenhagen are the surroundings included), and therefore the surrounding areas where the single-family neighborhoods are often found have not necessarily been included. The differences in percentages for the four areas are not seen as a factor affecting the usability of the results. Since the respondents are equally spread [figure 4], the results are seen as valid for all four regions and give an average picture of the Danish homeowner which can be equally truthful in each region.

[figure 4]

#### 4.2. Survey representativity, reply rate and uncertainty

There are differences in the numbers from the respondents group compared to the statistics. However, for the overall result processed in this paper, the differences will not make these numbers untrustworthy. The largest difference is the amount of men in the respondent group compared to the amount of women, but since these men are owners of their house their opinion are just as important as the female owners. The division is, therefore, not seen as distorting the results to a degree where they are less useful. The same is the case with the difference in the respondents' age compared to the statistics. The different answer given by the two genders don't differ significantly when compared. The age on the other hand has some influence on the results. Where these differences affect the results, it will be stated and discussed. Analysis of the respondents' replies according to the age has shown that there is a significant difference between the younger and the older generation. For instance is the younger generation more interested in energy retrofits than the older generation.

The survey is seen as representative despite some differences between the respondent group and the statistical data (an overweight of respondents in the older generation and of men). There are respondents in every category, and therefore the survey provides an indication of which parameters the homeowners are motivated by and can, as a result, contribute with valuable information to the existing knowledge about how the number of private energy retrofits can be increased.

Of the 4,000 selected homeowners 883 replied, giving a reply rate of 22%, and 87% of these replies came back via post. A confidence level at 95%, which is the typical used level of accepted uncertainty, a population of 440,000 (the approximate number of Danish single-family houses erected between 1960 and 1979) and 883 responses give a confidence interval at 3.3% with a random check calculator [17]. This means that the uncertainty of the results are within a span of  $\pm 3.3\%$  compared to if every single-family homeowner in Denmark had completed the questionnaire. To reduce the confidence interval by half, one needs four times the amount of responses. The certainty of the survey is between 91.7% and 98.3% (confidence level  $\pm 3.3\%$ ) which is found to be reasonable for the results to be applicable and trustworthy. It must nonetheless be mentioned that the above

calculations cannot recognise the high amount of respondents in the older generation and of men and therefore the results should be compared against results from individually analysis of age groups and the two genders.

## 5. HOW TO MOTIVATE HOMEOWNERS FOR ENERGY RETROFITS

The following chapter presents results from the survey by the use of five themes to define the motivation factors.

### 5.1. The homeowner view energy retrofits and what can increase the amount?

The respondents were asked about their interest in energy retrofitting of their homes, and more than half of the respondents (60%) had a medium interest in this, 33% had a great interest in private energy retrofits, and 7% said they had no interest in the subject.

Among the respondents, there was trust that energy retrofits will give lower energy consumption (72%), that the property value will increase after energy retrofit (44%) and that the retrofit will provide a better indoor environment (37%). On the other hand, did respectively 28% and 27% think that energy retrofits are too expensive and that the savings are not as high as expected [figure 5].

[figure 5]

In order to increase the number of private energy retrofits, the respondents were asked which conditions and/or initiatives they trust can make a positive difference. The results show that economic grants (70%), cheaper materials and work hours (49%) and easy access to unbiased guidance (33%) are the top three conditions which the respondents trust can increase the amount of private energy retrofits. They believe in neither law changes (9%) nor examples of architectural changes (how the architectural expression of the building can change as a result of a retrofit) (8%) [figure 6].

[figure 6]

### 5.2. Prioritisation of general parameters

Five parameters related to the home were evaluated individually throughout the questionnaire according to the importance for the homeowner. Indoor environment is the most important parameter followed by optimal layout/functionality and comfort. Architecture and energy consumption are weighted at the bottom [figure 7].

[figure 7]

The five parameters and three additional parameters were graded against each other on a scale from 0 to 7, with 0 being the least important and 7 being the most important parameter. Out of the eight listed parameters, the most important to the homeowners is the comfort of their house (4.9), followed by optimal lay-out/functionality (4.6), indoor environment (4.4) and operating cost (cost of heating, water, electricity, maintenance) (4.4). Architectural quality (1.6) is the least important parameter of the eight [figure 8], which also corresponds with the fact that just 22% of the respondents agreed with the statement; *Architectural quality is more important to me than energy savings*.

[figure 8]

### 5.3. Assessment of current house

The appearance of the house is just as they would like it to be for 39% of the homeowners, whereas 59% would like to change a few things, and 2% would change everything about the appearance if possible [figure 9]. At the same time, did 44% of the respondents say that they would like a more modern looking house, and 45% would not change the appearance of the house. This 45% presumably consists of the same 39% who has a house which is exactly as they want it and a few percentages of the respondents who would like to change only 1-3 things about their home's appearance.

[figure 9]

The lay-out/functionality of the houses is, as seen earlier [figure 7+8], very important to the respondents, and when asked about the present situation 56% of the respondents stated that their current lay-out was optimal for their household. 40% said it worked but was not optimal and 3% thought that the lay-out should be changed to meet the household needs [figure 10].

[figure 10]

To assess the current comfort and indoor environment, the questionnaire contained various questions about the homeowners' habits in the house and potential adaptations to avoid problems. The questions were both action questions i.e. how the homeowners acted in their house and experience questions i.e. how they experienced the everyday life in the house. The below table contains the replies where it is clear that the majority of the homeowners did not experience problems with the comfort and indoor environment [figure 11]. This corresponds with the grades given on a scale from 1-10 (poor-good) for the current comfort (7.6) and indoor environment (7.7) where the respondents seemed satisfied with the situation. When looking at the possible adaptation, there could

be indications that the homeowners have adapted to the given situation to avoid problems. This will be discussed in the next chapter.

[figure11]

#### 5.4. Need for retrofitting?

For each of the potential problem areas, the homeowners were asked what they thought about conducting an energy retrofit in order to avoid the given problem. The responses showed that the homeowners generally found it unnecessary to conduct energy retrofits with the purpose of removing problems [figure 12]. To reduce condensation on windows and draught and cold surfaces, there are however respectively 42% and 40% who saw it as a good idea.

[figure 12]

Despite the fact that the respondents did not find it necessary to perform an energy retrofit to remove problems, 71% and 74% respectively thought that a retrofit could improve the indoor environment and comfort of their house slightly or a lot. Only 20% and 18% did not think it would change anything [figure 13].

[figure 13]

The energy consumption of a house can be a large expense, and the homeowners appeared, presumably faulty, to be very optimistic about the size of their consumption. The homeowners generally thought that their energy consumption was low (37%) or average (59%) compared to similar houses and households. Only 4% considered their energy consumption to be higher than the average of similar [figure 14]. Reasons for this picture are discussed in the next chapter.

[figure 14]

#### 5.5. Willingness to renovate and acceptable costs

The respondents' current situation in terms of their willingness to conduct an energy retrofit is seen in the below figure [figure 15]. There is a larger number of respondents who stated that they, for various reasons, would retrofit their house than the number of respondents who would not retrofit. The respondents were able to choose as many statements as they liked, and statements concerning will to perform retrofits were chosen 1,959 times whereas statements about no will were chosen 991 times. The statements chosen by most respondents were “I

will renovate to get lower energy consumption” and “I will not renovate because I am happy with my house as it is today” which was chosen by respectively 56% and 45% of the homeowners [figure 15].

[figure 15]

Whether a retrofit job gives a visible result or not has very little influence on the willingness to retrofit. Only 6% of the respondents would only renovate if it gave a visible result, whereas 94% did not care if a potential retrofit was visible or not. When the respondents were asked about the importance of a visible result in relation to larger investments, as many as 33% stated that larger investments should be visible. However as many as 44% of the respondents furthermore stated that they would like a more modern looking house.

The willingness to perform a retrofit, if an improved appearance or comfort and indoor environment are included, was very high among the respondents. 66% said they would retrofit if they got improvements in the appearance of the house besides energy savings, and 72% would do it if they had better comfort and indoor environment included [figure 16].

[figure 16]

When it comes to the size of the investment required, there were some differences in how much improvements in the appearance, comfort and indoor environment respectively are worth to the homeowners. The respondents were more willing to pay extra to get an improved indoor environment and comfort than for an improved architecture. 22% would not pay anything for architectural improvements compared to 13% for comfort and indoor environment improvements. The willingness to pay extra for comfort and indoor environment are higher than for architecture. The majority of the responses were within the price span from 201 – 1,000 DKK (27-134 €) extra per month for both improvements. Only the highest price range (more than 1,000 DKK (134 €) extra per month) was similar for the two categories [figure 17].

[figure 17]

## 6. DISCUSSION

The high level of interest in energy retrofits found among the respondents cannot be seen as a general picture of the Danish single-family house owners' interest in retrofits. There are two conflicting parameters which affect the results in opposite directions. Firstly, the questionnaire is about energy retrofit, which is why it is expected that homeowners with interest in the subject are most likely to answer. So these numbers only tell that the average respondent has an interest in energy retrofitting, but it is expected that this picture would be less positive if compared to the average of all Danish homeowners. Secondly, there is an overweight of respondents in the over

60 years old generation compared to the statistical data [figure 3]. Further analysis of the questionnaire results, where the respondents among others are divided according to their age, has shown that this generation has less interest in energy retrofit than the younger generation. Therefore, the picture of the general interest is presumable influenced by this and would be more positive if the age of the respondents were similar to the statistical data. When looking at the willingness to renovate and at the money the homeowner is willing to invest [figure 17], the situation is the same. Here, the older generation once again brings down the average. They are also more satisfied with the current state of their house and do not see the same need for retrofits as the younger generation. The other aspect where the respondent group is very different from the statistical data is the distribution of gender [figure 2]. However, this does not have a significant influence on the results when answers from the two genders are compared.

The respondents seem to have some knowledge about the benefits an energy retrofit can bring, but at the same time the results clearly show that more knowledge is needed [figure 5]. The listed benefits are expected to be natural gains from a deep energy retrofit, but the homeowners have little knowledge about this potential. Information is especially required in relation to the expected improvements in architecture and lay-out/functionality. The current situation can be a picture of how the press coverage has affected the knowledge of the homeowners. In the past years, the Danish press has focused on energy savings, improved comfort and indoor environment as benefits from energy retrofits. The homeowners have by now more or less learned that these elements are parts of retrofits, however they still need to be reminded about this. This could also be the future case with the improvements in lay-out/functionality and architecture if the press focus is also turned in this direction. The majority of the respondents trust that an energy retrofit will give lower energy consumption, but there are still some who do not believe in this [figure 5]. Previous studies [7,16] state that this is one of the barriers for energy retrofit, and this survey shows that there are in fact homeowners who do not see energy savings as a natural consequence of energy retrofits. However, it cannot be verified from this survey whether this is a barrier that holds back these respondents. Another reason why homeowners do not renovate can be that they think they have low or medium energy consumption [7,9], and results from this survey indicate that this could also be the case. Most of the homeowners believe their consumption to be low or average [figure 14]. This could, as the authors see it, indicate one of two things: 1. The homeowners do not know the actual size of their consumption and the average size of similar households and then some of them have a high consumption without knowing it. This indicates an ongoing need for better information and more understandable energy bills. 2. The respondents have already retrofitted their houses or installed other energy saving objects to reduce the consumption in which case the results could be true. The authors consider the first case to be the most realistic, and if the consumption is believed to be low, the homeowners naturally do not see a need for energy savings. These examples clearly state that there is still a need for more information about all aspects of energy retrofits,

but this conclusion is not shared by the homeowners. They instead consider economic help and support in different variations as the way to change the current situation, while forcing them to conduct retrofits by law changes or increased energy prices are not seen as productive approaches [figure 6].

The homeowners were generally very satisfied with their comfort and indoor environment and do not experience many problems, but the results however suggest that an adaption has taken place to avoid the possible problems in more cases [figure 11]. The comfort and indoor environment are very important to the house owners [figure 7+8], and since these parameters are of great influence to their wellbeing, they will naturally adapt to make the best of the situation. The high grades given for the current situation can mean one of two things; either they do not know how good comfort and indoor environment could be or they have simply adapted to the situation to avoid a given issue. For example, more than half of the respondents say that persons in the household wear thick socks, slippers or similar for the most parts of the year [figure 11]. This indicates that there is a problem with cold floors due to draught and/or poor insulation, which the respondents have adapted to by putting on warm footwear. This might explain why 66% say that they do not experience the floors as being cold [figure 11]. The remaining part notices the cold floors either because the problem is bigger here and socks are not enough to keep warm, or because they have not put on footwear to keep the cold away. Even though the respondents are satisfied with their comfort and indoor environment, some do believe it would be a good idea to retrofit in order to reduce some problems which can be health related, namely draught and cold surfaces and also to reduce condensation on windows [figure 12], which is also where most experience problems [figure 11]. For the remaining potential issues a retrofit is seen as being unnecessary. Regardless of the present satisfaction, the homeowners are aware that an energy retrofit can offer even better conditions than what they currently experience [figure 13]. There is, nonetheless, still a need for generating awareness towards the potential problems and benefits by removing these problems through energy retrofits. The homeowners know that an energy retrofit can give better comfort and indoor environment [figure 5+13], but in order for them to utilize and benefit from this, they have to be aware of and acknowledge that there is in fact potential problems and a need for improvements in their house.

Lay-out/functionality of the house has proven to be among the most important parameters for the homeowners whereas architectural quality is the least important [figure 7+8]. The two aspects of architecture, architectural quality and lay-out/functionality, are rated very differently. Lay-out/functionality is rated second highest indicating that the inside of the home and how this works for the family is very important, while the exterior is not important in comparison to other parameters. Also in the assessment of the two aspects large differences are seen; The homeowners were generally satisfied with the current lay-out/functionality [figure 10]. The appearance is assessed differently: here almost half of the homeowners would like a more modern appearance of their house and more than half would like to change something about the current appearance [figure 9]. This indicates again



that the lay-out/functionality has the prime attention of the homeowners. There is, nonetheless, a desire to change and update the appearance, and therefore this should not be eliminated as a potential motivation factor. Since deep retrofits in most cases will cause changes in the exterior architecture, the desire for changes can be combined with energy savings. Thereby the investment might not be much higher than if only the appearance was changed, but the benefits will be much larger if energy savings are included in the work.

The relative low rating of energy consumption [figure 7+8] could explain why the amount of deep energy retrofits has not yet had an actual boom despite the potential and publicity. The focus has often been on energy savings, and if this is not of high importance to the homeowners they are not willing to spend a large amount of money on this. These evaluation results indicate that improvements in comfort, indoor environment and lay-out/functionality presumable will be better motivation factors since they are important to the homeowners [figure 7+8]. Whereas improved architectural quality is not seen as an obvious unassisted motivation, meaning that the main focus should be on the potential benefits which the homeowners would experience from the inside of the house and in their everyday life and then supplemented by the exterior improvements.

A very large percentage of the respondents state that they will conduct an energy retrofit, if only the comfort and indoor environment or the architectural expression is improved [figure 16], but these numbers are, however, seen as a bit too optimistic since there are various other parameters which also come into play. The economy is very important when it comes to reasons for retrofitting [figure 15], and therefore the authors trust that these numbers will only be realistic if the investment size and energy savings even out each other within a short period of years or the extra investment to get the improvements is relatively low. On the other hand, the respondents are willing to spend some extra money a month for both improvements in appearance and comfort and indoor environment in relation to an energy retrofit [figure 17]. The picture of the willingness to invest more in improvements can be negatively affected by the fact that many of the respondents are retirees or receivers of early retirement (42%), who do not have the will to invest a large amount of money. One of the respondents has commented the questions about extra monthly payment for improvements: *"we are too old to make major investments, we have a good house, which certainly can be improved, but we make do with just changing the windows"* (edt.translated). This comment reflects many of the comments about the economy and size of investments and clearly shows that the older generation will be hard to motivate to invest a lot of money in an energy retrofit. The younger generation still has many years to live in their house and so they ought to be more motivated to improve the house on various parameters, since they can benefit from this for many years. The important thing to take away from this is that there is in fact a willingness among the homeowners to pay for improvements, which in many cases are included for free in energy retrofits. This means the budget for future projects can be increased because of these improvements. Furthermore, these results signify that the

architectural appearance, despite the bad rating at the importance scale, could be motivation and reason for increasing the budget.

The willingness to renovate is, as expected, highly connected to economic benefits and size of investments. When the homeowners have reasons for performing retrofitting of their house, the top three reasons for doing it are related to economy, and in the top three reasons for not conducting retrofits two out of three are likewise related to economy [figure 15]. From these results, it is clear that the economic aspects of energy retrofits are not to be forgotten in the motivation process. Even though the interior lay-out/functionality, indoor environment and comfort are rated as the most important aspects to the homeowners [figure 7+8], the economy is the critical aspect and it should be reasonable for the homeowner before the motivation factors have an effect. The main argument for not renovating is that they are happy with their house as it is today [figure 15]. If this is in fact the case for 45% of all single-family house owners, the potential of 7,811 TJ [5] is no longer realistic, but can drop down to approximately 4,300 TJ instead. This again signifies that it is important to motivate those who can be motivated and to increase the knowledge about the potential gain and improvements for those who currently are not willing to renovate. In any case, both information and motivation are crucial.

Previous reports [7-12] have suggested a variation of incentives and solutions to overcome defined barriers for energy retrofits in private Danish homes. The difference of these results and the results from this survey is primarily the basis of the results. Where the previous reports are built on information from other reports or calculations, workshops, interviews and meetings with key persons within the field, this survey has had the homeowner as basis and as many as 883 completed contributions from across the country. It is believed that this survey has a high value for the future work of motivating homeowners since the persons to motivate are the ones questioned. Furthermore, the amount of respondents gives a good foundation for a general assessment of how the Danish single-family homeowner thinks, prioritizes, acts and invests instead of conclusions based on a fusion of previous reports or a few key persons or experts' opinion on how to solve the problems. The results are perceived strong enough to give ideas on how to precede towards an increase in private energy retrofits, but also as a good supplement to and strengthening of previous surveys and an input to the energy retrofit debate.

## 7. CONCLUSION

From the results presented, it is clear that the perceptible and visible improvements in comfort, indoor environment and lay-out/functionality can be used to motivate homeowners to conduct energy retrofits. Energy consumption and architectural appearance are, on the other hand, not rated high and therefore it is not realistic that either of these parameters alone can be sufficiently motivating for the majority of homeowners. At the same time, it is very important that the economy of the projects is sensible and that the part of the investment which is not covered by future energy savings is not too high if the projects are to be found advantageous. The economy

of the projects is the deal breaker. It can either initiate or call off a project, and the importance of this aspect is not to be overlooked. The homeowners will however pay extra each month to get improvements in comfort, indoor environment and architecture and this extra investment ought to be utilized in future retrofits projects to increase the total budget.

The approach expected to generate the most future success is a combination of information about the current state of the house and energy consumption, education in and motivation by improvements in the non-economic parameters, and a sensible investment size possibly supplemented with a financial grant. The task of educating the homeowners is expected to be difficult, but is nevertheless a very important part of the strategy if the amount of private energy retrofits should increase.

Although this is a Danish study, the results tell something general about the importance of asking the end user and not only concentrating on what politicians and professionals believe. The results have shown that energy consumption is not among the homeowners' top priorities and therefore the tendency of focusing solely on energy /economical saving is fine part of the way, but cannot stand alone and should be supplemented by other initiatives. These initiatives can be determined by similar studies where the homeowners' preferences are examined and his motivation factors are defined.

Conclusively, the results from this survey are seen as useful for society unsupported by other research due to the large amount of respondents and the geographic spread of these. The result can however also support and strengthen some of the previous reports which share the view on solutions but where the homeowners have not been an active part of the surveys.

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figure 1: The four areas in which the questionnaire has been distributed with 1,000 examples in each region.

figure 2: Distribution of gender in the respondents group compared to statistical data from Statistics Denmark of the distribution in Danish single-family houses erected between 1960 and 1979, for persons over 18 years of age [15].

figure 3: Age distribution of respondents compared to statistical data from Statistics Denmark of the age distribution of occupants in Danish single-family houses erected between 1960 and 1979. [15]

figure 4: Geographic spread of the respondents. Odense; 27% of the respondents, Copenhagen; 26%, Aarhus; 25% and Aalborg; 23%.

figure 5: Opinions on energy retrofits. The respondents were allowed to pick as many statements as wanted.

figure 6: The most important parameters in order to increase the number of energy retrofit. The homeowners each picked three parameters in which they trust.

figure 7: Five parameters evaluated individually according to their importance.

figure 8: Parameters rated against each other according to their importance to the respondents.

figure 9: Assessment of current architectural appearance.

figure 10: Evaluation of the current lay-out/functionality in relation to the households needs.

figure 11: The homeowners' adaptation and experience of potential problems.

figure 12: The respondents' view on conducting energy renovating to avoid a potential problem.

figure 13: Belief in improved indoor environment and comfort by energy retrofit.

figure 14: The respondents' estimated energy consumption compared to similar households.

figure 15: Statements describing the respondents' current situation. The respondents were allowed to pick as many statements as they wanted.

figure 16: Willingness to invest in energy retrofit if improved architectural appearance or comfort and indoor environment are included.

figure 17: Willingness to pay extra for an improved architectural appearance or improved comfort and indoor environment.

figure 1



figure 2

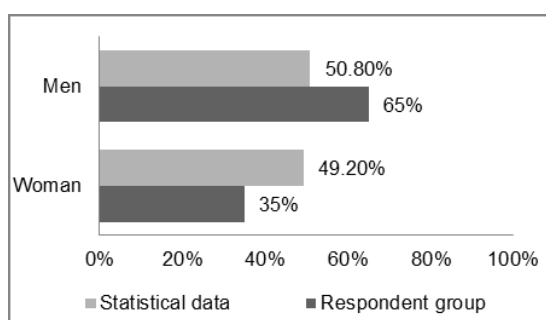


figure 3

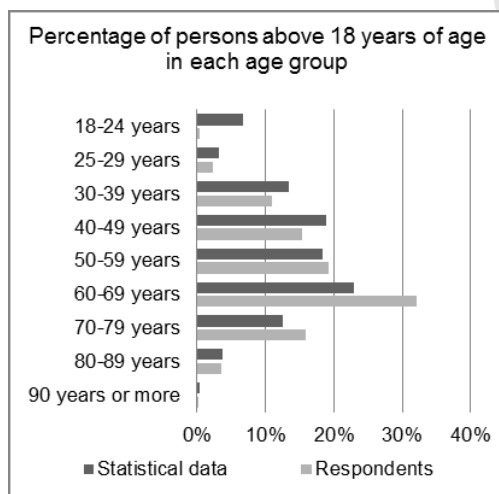


figure 4

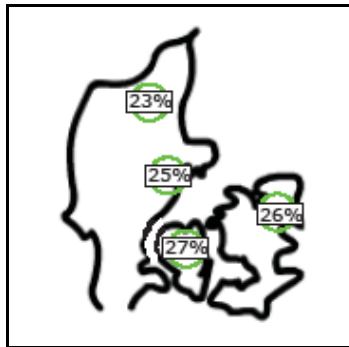


figure 5

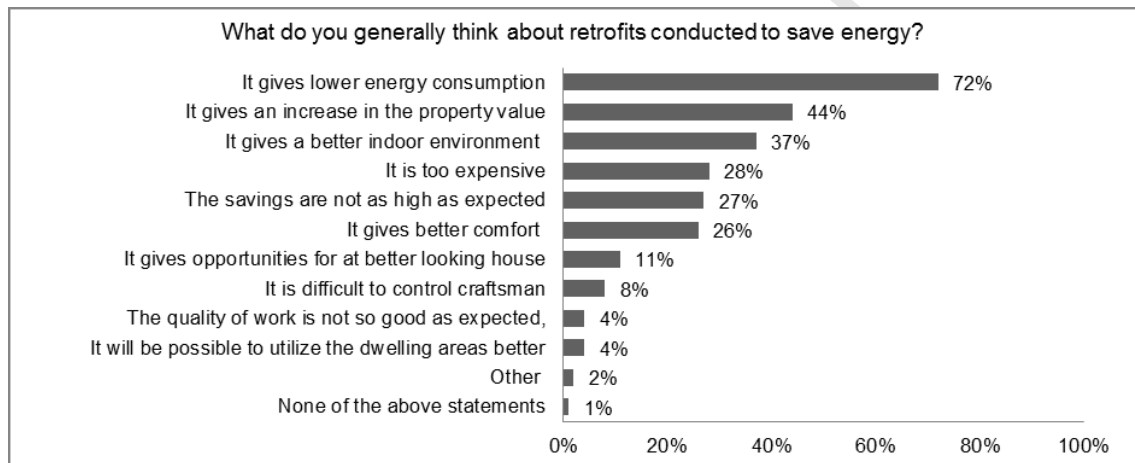


figure 6

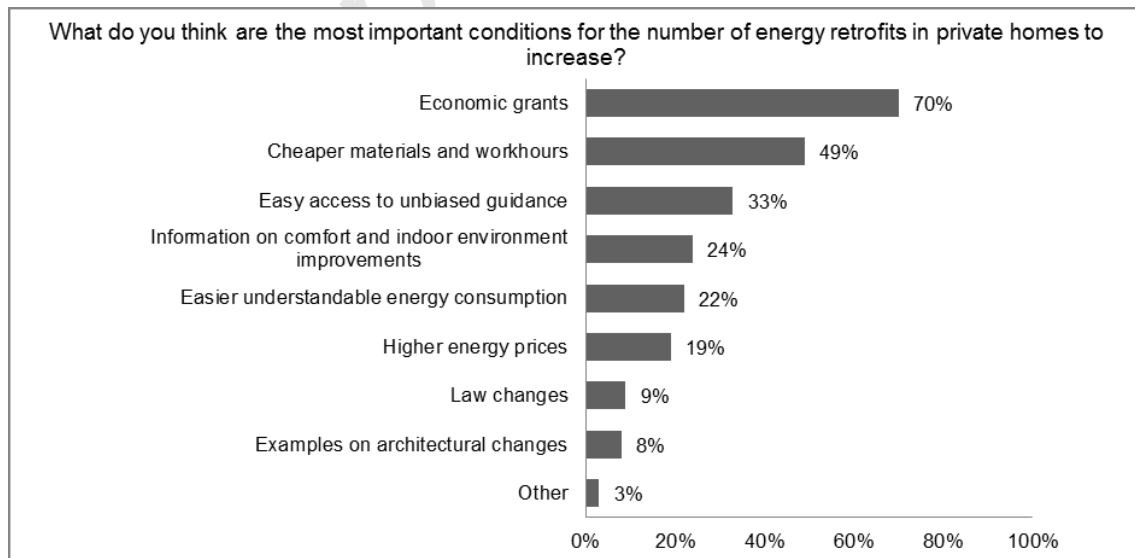




figure 7

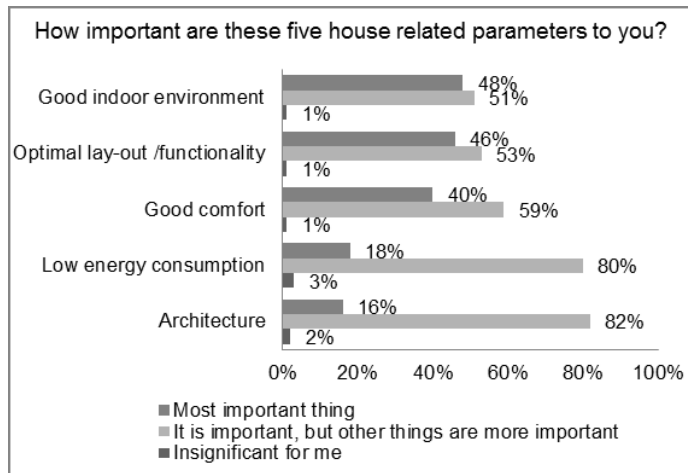


figure 8

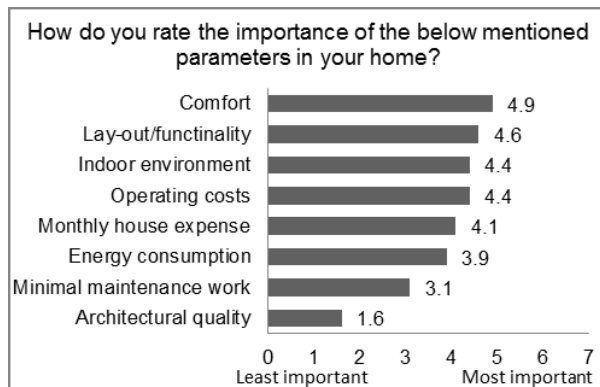


figure 9

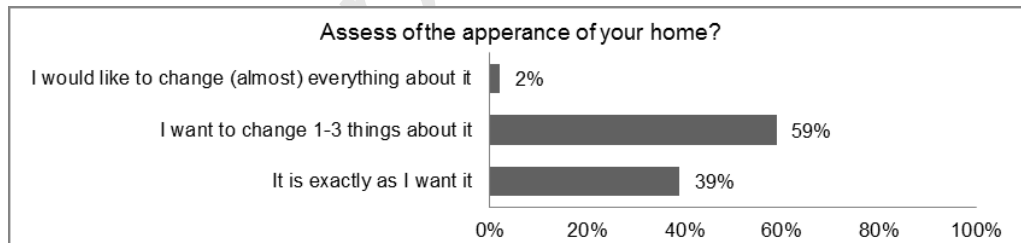


figure 10

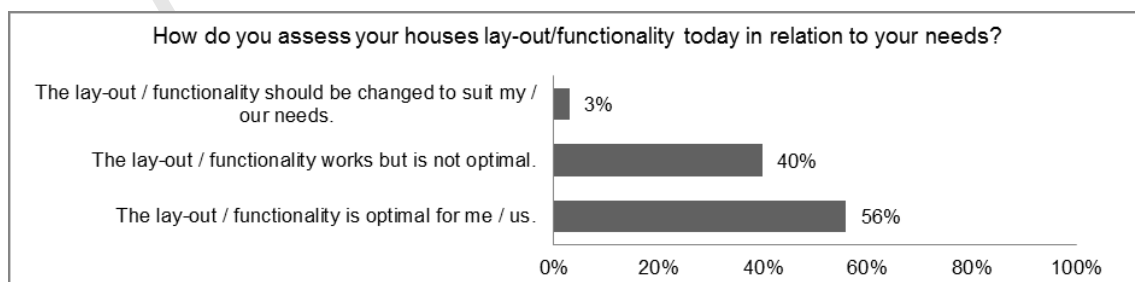


figure 11

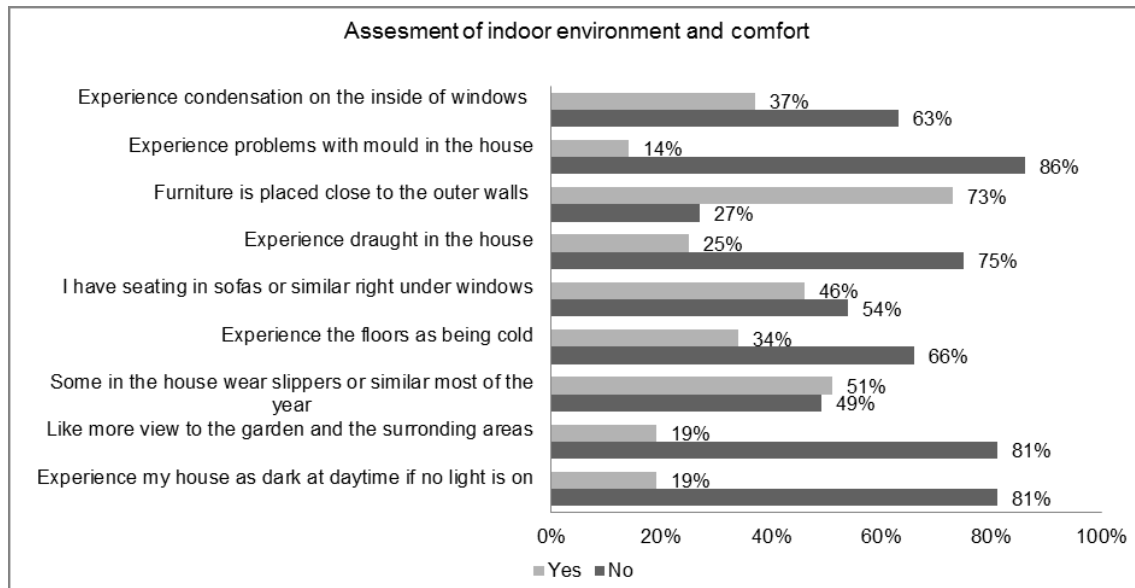


figure 12

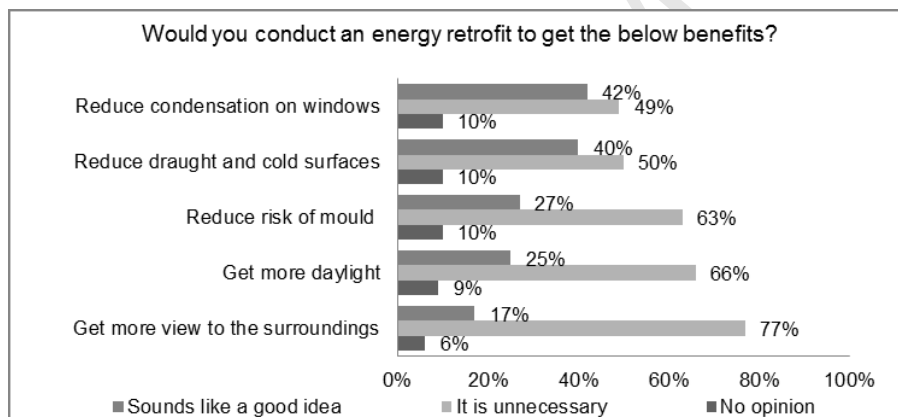


figure 13

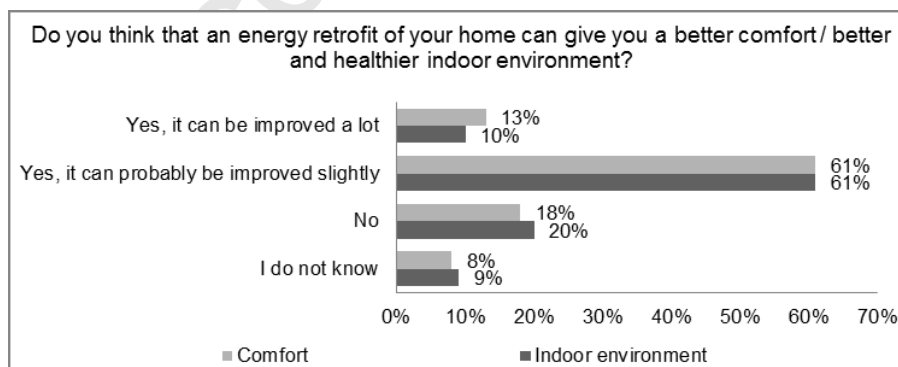


figure 14

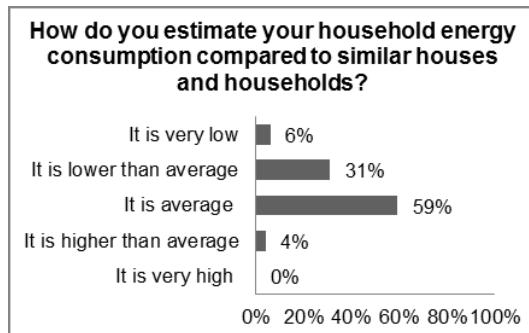


figure 15

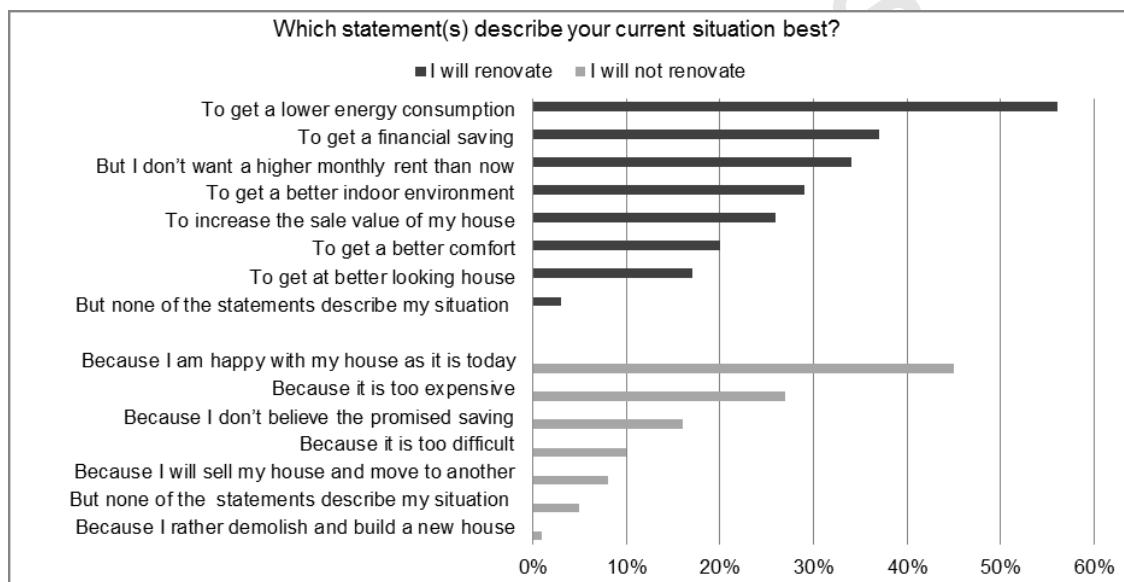


figure 16

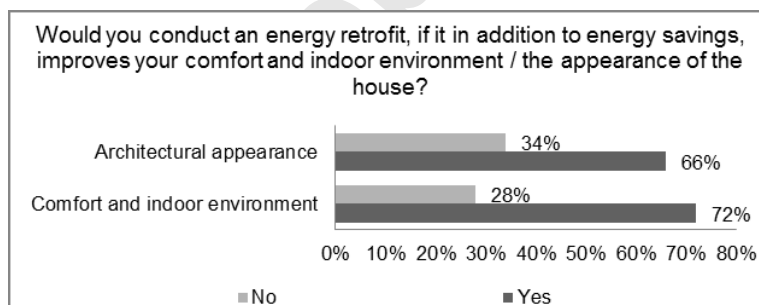
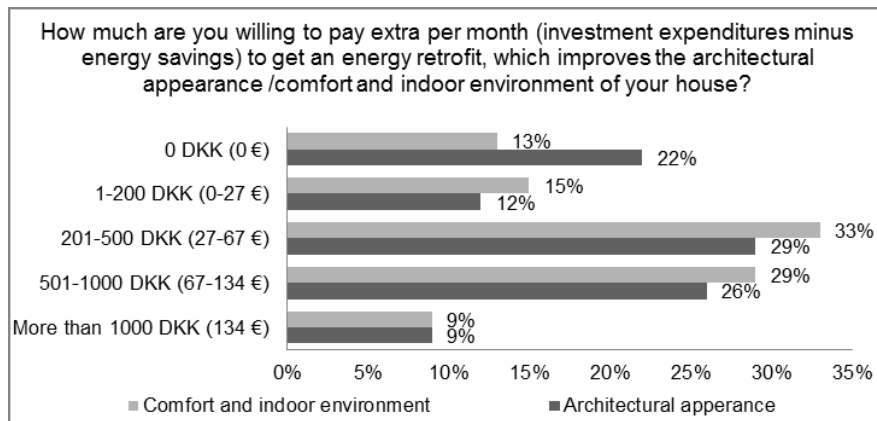


figure 17



**Highlights**

883 homeowners participated in questionnaire survey about energy retrofit

Energy savings cannot motivate homeowners to conduct private energy retrofits

Motivation factors are improvements in comfort, indoor environment and architecture

Knowledge of non-energy benefits and consumption increases the retrofit number

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